Key Terms
wind farm
solar energy
photovoltaic effect
biomass energy

12.4 Sustainable Sources of Electricity

A pie chart, like the one in **Figure 12.17** on page 501, shows how electricity is generated in Ontario. The chart is updated as the demand for power changes during the day. At the present time, our generating stations use mostly nuclear power, hydroelectric power, gas, and coal. What will this pie chart look like in the future, as some generating stations need to be replaced and Ontario's population grows?

There are very few remaining sites that are suitable for developing new hydroelectric stations, and the other types of generating stations make significant impacts on the environment. Future plans include conservation and the increased use of renewable forms of energy.

Wind energy, for example, presently contributes only about 1 percent of electrical energy, but there is the potential for a much greater contribution. As **Figure 12.21** shows, wind turbines can make both large and small contributions to our energy needs.

In this section, you will learn how electricity can be generated using renewable forms of energy and how electrical energy can be conserved.

Figure 12.21 Some wind generators are part of large wind farms that are linked to the power grid. Other wind generators, like the one shown in the inset photograph, are used to provide electricity to a single home or farm.

Renewable Sources of Energy

Electrical energy is always generated from another source of energy. Fossil fuels like coal, oil, and natural gas took millions of years to form, and their supplies are limited. Uranium, the fuel that is used to generate nuclear energy, was present when Earth formed, and no more will be produced by natural processes. As you learned in section 12.3, these are examples of non-renewable energy sources. However, there are many energy sources that are renewable. Hydroelectric power is one example. Others include wind, solar, ocean (tides and waves), biomass, and geothermal.

Wind Turbines

Figure 12.21 shows many large wind turbines at one location, called a **wind farm**. A single turbine, which may supply electricity to a farm, home, or small business, operates in much the same way. The most common type of wind turbine in Canada is mounted on a tower, usually 30 m or more above the ground, to take advantage of greater wind speeds. The height above the ground also reduces turbulence, or irregular air motion, which results from wind blowing around buildings.

wind farm many large wind turbines at one location

How Wind Turbines Work

Figure 12.22 shows the main parts of a large wind turbine. A wind turbine begins producing electricity when the wind speed is about 13 km/h (kilometres per hour). The power that is generated increases with wind speed until it reaches a maximum at about 55 km/h. For safety reasons, the controller activates a brake to shut down the turbine when the wind speed reaches 90 km/h or more. The controller contains circuits that maintain output from the generator at a frequency of 60 cycles a second alternating current.

The Promise of Wind Energy

The potential for generating electricity from wind turbines is good in Ontario and other parts of Canada. In particular, Ontario's Great Lakes provide very good sites for wind farms. At the end of 2008, Ontario led all the provinces in the capacity to generate electricity from wind, with more than 950 MW—providing enough energy to supply nearly 250 000 homes.

When wind turbines are installed and connected to the grid, the cost of running them is very low. The major technical disadvantage of generating electricity from wind is that the wind speed at any location may vary during the day. There are also concerns that wind turbines spoil the view, are noisy, and can be a danger to birds and humans nearby.

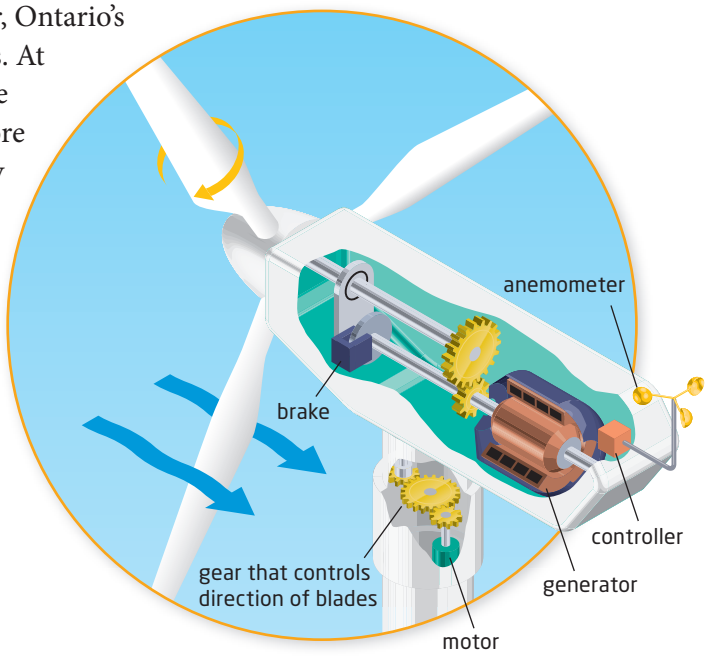


Figure 12.22 The gears in the gear box increase the speed of rotation of the shaft. The motor and the gears that are next to it control the direction of the blades. A large turbine can generate a few megawatts of electrical power. Most smaller turbines do not have a system of gears.

solar energy energy that is directly converted from the Sun into electricity

photovoltaic effect the generation of a direct current when certain materials are exposed to light

Sense of Value

According to the Canadian Energy Research Institute, in 2003, solar photovoltaic was the most expensive form of electricity generation in Canada, at a cost of as high as 80 ¢/kW·h. Coal was among the cheapest, at no more than 7 ¢/kW·h. However, it was estimated that by 2030, the cost of solar photovoltaic energy would decrease by up to 65 percent.

Solar Energy

The Sun is the ultimate source of all the different forms of energy we use, except nuclear and geothermal energy. Fossil fuels are the result of energy from the Sun being captured by vegetation millions of years ago. Today, the Sun is the energy source of biomass, wind, and hydroelectric generators. Usually, however, the term **solar energy** means energy that is directly converted from the Sun's energy into electricity.

The Photovoltaic Effect

In 1839, the French physicist Edmund Becquerel discovered that certain materials produce an electric current when they are exposed to light. This is called the **photovoltaic effect**. Photovoltaic materials in a solar cell generate direct current when light strikes their surface. You may have a calculator or wristwatch, or an external light on your home, that uses solar cells. **Figure 12.23** shows a parking meter that uses solar cells.

The Sun emits enormous amounts of energy. The challenge is to collect and convert this solar energy to electrical energy efficiently and cost-effectively. Above the atmosphere, the energy that is received from the Sun averages 1367 W/m^2. Thus, a 1 m^2 solar cell, operating at 100 percent efficiency, could easily supply the power necessary to operate most electrical appliances. At Earth's surface, this efficiency is about half. We receive only about 700 W/m^2.

STSE Case Study

Off the Grid and Living Green

Alternative energy sources such as solar and wind power make it possible to generate your own electricity supply.

Comparison of Energy-Efficient and Standard Appliances

Appliance	Average Energy Consumption (kW·h/year)	Consumption of Most Energy-efficient Model (kW·h/year)
Refrigerator	465	347
Dishwasher	457	344
Clothes washer	573	264

Cam and Brenda Snell live year-round in Silver Islet, Ontario, about 80 km from Thunder Bay and 8 km from the nearest power lines. Silver Islet is not connected to the power grid, which means that the community does not draw electricity from Ontario's network of generating stations and transmission lines.

Many local residents use gas generators when they need electricity. The Snells, however, decided to power their house with renewable energy sources. They installed a solar/wind hybrid system consisting of four 75 W photovoltaic cells (solar panels) on the roof of their house and a 1300 W two-blade wind turbine on a cliff behind their house. In addition, the Snells purchased energy-efficient appliances.

Solar Energy at Earth's Surface

To find out the useful amount of solar energy that a solar cell would receive, its position on Earth needs to be considered, as well as weather and seasonal changes, including the number of daylight hours. For Ontario, the average energy at Earth's surface is between 3.3 and 5.0 $kW \cdot h/m^2$.

Costs of Solar Energy

The commercial solar cells that are now available are, at best, about 25 percent efficient. A single family home might have a roof area of about 30 m^2 facing the Sun. Thus, assuming that 4.0 $kW \cdot h/m^2$ of energy is available on an average day, the electrical energy that could be generated is $4.0\ kW \cdot h/m^2 \times 30\ m^2 \times 0.25 = 30\ kW \cdot h$. In a 24 h period, only 1.7 kW of power is available, much less than what is usually needed in a home.

This example illustrates two of the problems with solar energy: it is not very concentrated, compared with other sources, and solar cells are not very efficient. A third disadvantage is the high cost of solar energy systems. Solar cells generate DC, and batteries are needed to store energy for use at night and on cloudy days. To supply energy to the grid, or to appliances that use AC, special electronics are required to convert DC to AC. The advantage, of course, is that the fuel is free, and there is very little negative impact on the environment.

Figure 12.23 Solar cells are becoming more common on our streets. They are used in parking meters, shown here, as well as traffic signals.

Combining Solar and Wind Energy

The solar and wind parts of the hybrid system complement each other well. In the summer, when the days are longer and there are more hours of sunlight, the solar panels provide most of the Snells' electricity. In the winter, the area is quite windy, so the wind generator takes over.
If excess energy is produced by the solar panels or wind generator, it can be stored in a bank of four lead-acid batteries. If there are long stretches without enough sunshine or wind, the Snells have a propane generator they can use. This is seldom necessary, however.

The Snells' total investment was about $40 000, which included the solar cells, the wind generator, the batteries, and all the other necessary electrical equipment. Bringing hydro wires into the community would have cost the Snells more. Since the Snells are not paying an electricity bill every month, they figure that their system will pay for itself in 20 to 25 years. Their choice was not just about saving money, however. It was about reducing their impact on the environment. Regardless of whether we live on or off the power grid, that is a choice all Canadians need to make.

Your Turn

1. Where do you see opportunities (big or small) in your community to generate electricity from renewable energy sources?
2. By purchasing electricity from a company called Bullfrog Power, residents of Ontario continue to draw power from the Ontario energy grid but also support locally generated renewable energy. Purchasing electricity from Bullfrog Power currently adds about $1 per day to an average electricity bill. Despite the extra cost, would you switch to an energy provider like Bullfrog Power? Why or why not?
3. Ontario has started a system called net metering. Research this system, and write a newspaper article that explains how net metering works in Ontario.

Ocean Wave Energy

Ocean waves can be used to generate electricity. The oceans on Canada's east and west coasts could meet our need for electrical energy many times over. The vertical rise and fall of the waves can be used to compress an air column, which drives a turbine that is connected to a generator. Canada is one of several countries that are investigating ways to generate electricity using ocean waves.

Tidal Energy

Study Toolkit

Creating a Word Map
How can a word map that organizes information about the word *renewable* help you remember different types of renewable energy?

At Annapolis Royal, in Nova Scotia, a large natural basin and tides that change the height of the water by several metres are being used to generate electricity, as shown in **Figure 12.24**. A dam was built, with gates that allow water to enter the basin. At high tide, the gates are closed, trapping water in the basin. When the tide retreats, lowering the water level, the gates are opened. As the water leaves the basin, it turns turbines. One problem is that tides vary on a 15-day cycle. Another is the presence of boat traffic. Also, tidal stations only generate electricity for about 10 hours each day, as the tide is moving in or out. However, tides are predictable, unlike winds.

Biomass Energy

biomass energy energy that is generated from plant and animal matter

Biomass energy refers to energy that is generated from plant and animal matter. The burning of plant matter at biomass stations adds carbon dioxide to the atmosphere, but the process is said to be "carbon neutral." This is because plant combustion returns to the atmosphere only as much carbon as the plants absorbed during their growth. Compared with burning fossil fuels, especially coal, the use of biomass energy results in much less acid rain, and no heavy metals are emitted. A large and convenient supply of biomass is not available, however, unless agricultural land and forests are used for this purpose.

Geothermal Energy

Geothermal energy is produced from naturally occurring steam and hot water that is heated by hot rocks and trapped under Earth's surface. When pumped to the surface, the steam drives turbines to generate electricity. There are few, if any, emissions from geothermal plants and they can provide base-load electricity with low running cost. However, suitable reservoirs of very hot water are deep underground, and the cost of drilling to extract the water is high. In Canada, the best prospects for geothermal energy are in British Columbia.

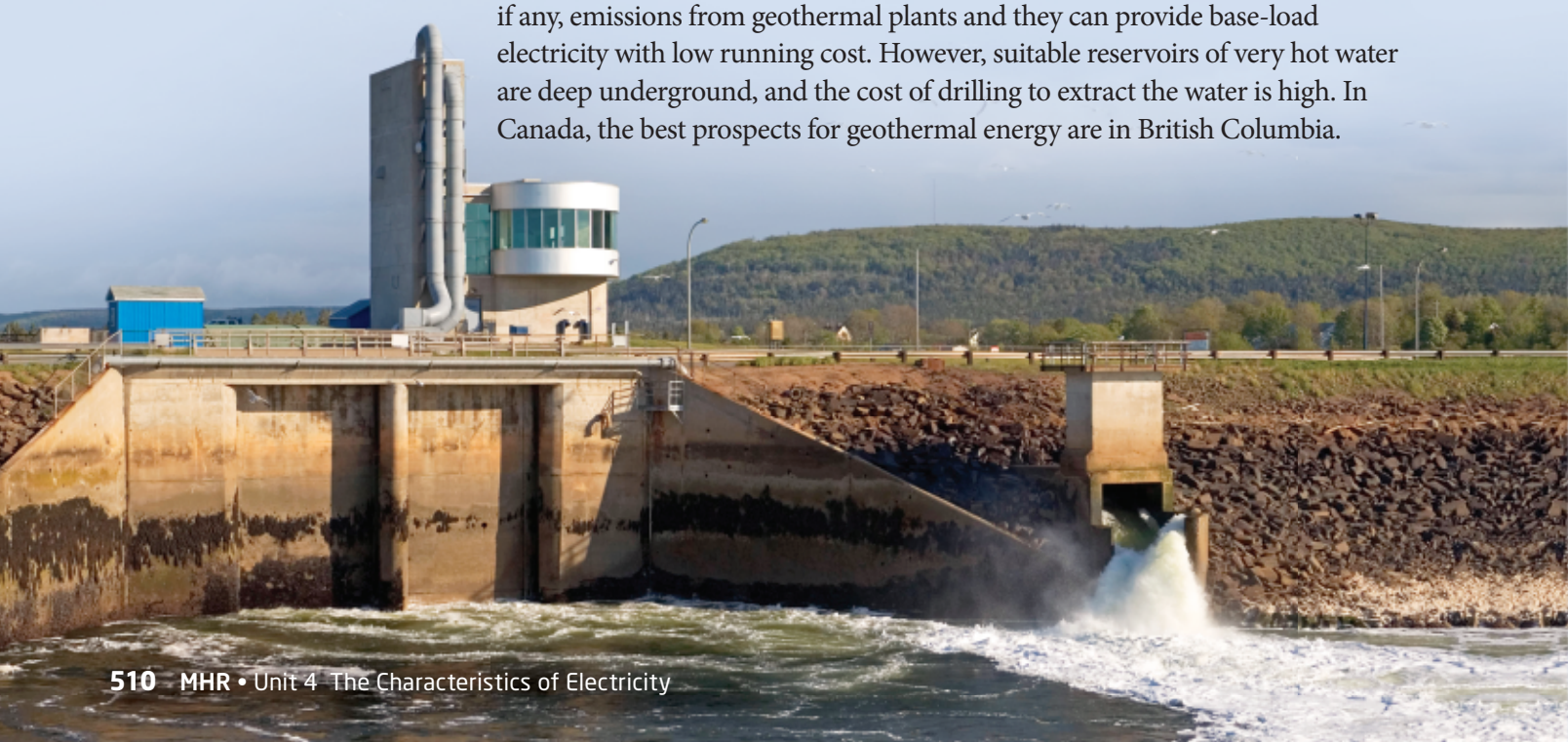


Figure 12.24 The Annapolis Royal generating station is the only modern tidal generating station in North America.

Conserving Electrical Energy

As you know, electrical energy is generated using other forms of energy. Each form of energy has an economic cost and an environmental cost. Switching energy use to off-peak times lowers the costs and reduces the effects on the environment. Using less electricity saves even more, both in costs and in effects on the environment. Governments and utility companies have a key role to play in energy conservation. For example, to meet projected demand, the Ontario government might decide to spend $1 billion to build a new generating station. An alternative is to offer incentives that encourage conservation and to pass legislation that requires change.

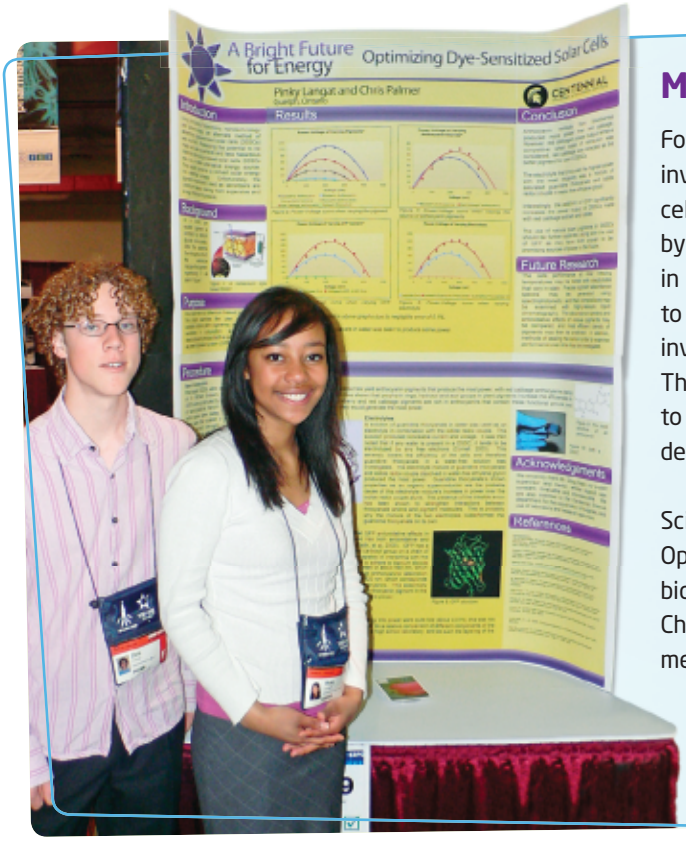
Ontario introduced the Great Refrigerator Roundup program in 2007 to remove older, inefficient refrigerators, freezers, and window air conditioners. The EnerGuide program, which gives consumers information about new appliances, was initiated by Natural Resources Canada. In some regions of Ontario, residents can sign up for the "peaksaver® program. This program allows the local utility company to install a device, operated wirelessly, that reduces the electricity used by a central air-conditioning unit.

The common incandescent bulb, used in homes for about 100 years, will be banned for sale in Ontario beginning in 2012. Smart meters will provide homeowners with the information they can use to reduce their energy bills. None of these initiatives can be successful, however, without individual action.

Suggested Investigation

Plan Your Own Investigation 12-D, Every Kilowatt Counts, on page 516

Go to **scienceontario** to find out more



Making a Difference

For their 2008 science project, Pinky Langat and Chris Palmer investigated dye-sensitized solar cells (DSSCs) because these cells mimic photosynthesis. They had both been amazed by the efficiency of photosynthesis when they studied it in biology class. DSSCs can be cheaper and less hazardous to produce than other types of solar cells. Pinky and Chris investigated how DSSCs could be made as efficient as possible. They produced and tested DSSCs using different components to increase electrical efficiency. Their work produced a unique design that improved efficiency by 10 percent.

Pinky and Chris won several awards at the Canada Wide Science Fair for their project, "A Bright Future for Energy: Optimizing Dye-Sensitized Solar Cells." Pinky is now studying biochemistry and international relations at McGill University. Chris is studying engineering at Queen's University and is a member of the Queen's Fuel Cell Team.

What organizations could you join to help promote government and corporate funding of research into sustainable energy technologies?

Section 12.4 Review

Section Summary

- Renewable sources of energy can be renewed within a reasonably short period of time.
- In Ontario, the renewable energy sources that contribute to electrical energy are wind, hydroelectric, and solar energy.
- Other renewable energy sources include waves, tides, biomass, and geothermal.
- Solar photovoltaic cells are semiconductor materials that generate a direct current when light shines on them.

Review Questions

K/U **1.** Explain the difference between renewable and non-renewable energy sources. Give an example of each.

A **2.** Refer to **Figure 12.22**. What is the function of the controller in a wind turbine?

K/U **3.** What are the advantages and disadvantages of photovoltaic cells?

K/U **4.** Why are photovoltaic cells sometimes used to provide electrical energy for a home or business in a remote location?

T/I **5.** Solar cells are commonly used to provide electricity for satellites. What advantages do solar cells have in space, compared with similar solar cells on Earth's surface?

K/U **6.** Why is biomass combustion considered to be carbon neutral?

A **7.** Contact your local utility company to find out how it helps its customers conserve energy. Make a summary, and identify any energy-saving incentives that would benefit your family.

T/I **8.** Examine the map below. What conditions in the Bay of Fundy make it a possible source of tidal energy?

The Annapolis Royal tidal station is located on the Bay of Fundy.